



March 14, 2008

Alaskan Way Viaduct Stakeholders Advisory Committee  
c/o Alaskan Way Viaduct and Seawall Replacement Program  
999 Third Ave., Suite 2424  
Seattle, WA 98104

Dear Committee:

On behalf of Cascadia Center at Discovery Institute, we want to commend your efforts to thoughtfully consider new alternatives for replacing the Alaskan Way Viaduct. As you know, the decision about what to do with Seattle's Viaduct will have a lasting impact on the city, its citizens and the economy of the region for decades to come. We appreciate your service.

As the committee observes the deliberations and the project team ultimately delivers its final report, we would like to encourage a fair evaluation of the inland bypass deep-bored tunnel for replacing the Alaskan Way Viaduct. Cascadia continues to strongly support the guiding principles agreed to by the state, county and city for this decision process.

In 2006, Cascadia commissioned a study of deep-bored tunnels by ARUP, a leading worldwide engineering and consulting company. In December 2007, we sponsored an international tunnel symposium kicked off by local legend Dick Robbins, former president of the company that pioneered TBMs (Tunnel Boring Machines) for the Channel Tunnel. While our organization has a record of supporting surface transit options, from bus rapid transit to streetcars and passenger ferries, we also believe that the congestion that would result without replacing Viaduct "thru" traffic capacity would create extreme problems. The inland bypass deep-bored tunnel deserves serious consideration as a workable, effective option, for several major reasons.

First, since the project team evaluated it in 2001, tunnel technology in the last several years has advanced exponentially in terms of construction speed, cost reduction and funding mechanisms. The technology since 2001 has blossomed tremendously to include 50-foot diameter TBMs. The enclosures to this letter illuminate elements of this new technology.

Second, it is important to note that Seattle has vast experience with tunnels, both historic and contemporary. There are more than 100 tunnels in the area, totaling over 65 miles in length. Two current deep-bored tunnel projects in the area are worth noting: the Sound Transit light rail tunnel through Beacon Hill and the Brightwater sewage tunnel.

Third, the deep bore bypass option could be constructed largely without disruption to the downtown and region's economies. The economic impact study we helped sponsor a year ago showed such disruption would cause a self-inflicted recession with an annual impact between \$2.2 and \$3.4 billion. This may be the single biggest benefit of this construction technique:

- There would be minimal utility diversions with a deep-bored bypass tunnel.
- Trucking of materials would be from the portals, reducing construction traffic in downtown and waterfront areas.
- Construction disruption downtown and especially at the waterfront will be minimized, allowing the port and waterfront businesses to stay in business.

**RECOMMENDATIONS TO ALASKAN WAY VIADUCT STAKEHOLDERS ADVISORY COMMITTEE**

**CASCADIA CENTER  
DISCOVERY INSTITUTE**

Importantly, compared to the Viaduct, a deep-bored bypass tunnel would be less disruptive to commerce and community. Also, many other minor factors suggest an examination of deep bore tunnels would be productive: Tunnels are the safest place to be in earthquakes, and they have the longest life when maintenance and replacement costs are considered.

Although there are those who strongly favor an elevated structure to replace the Viaduct, experience shows that in the long run, elevated structures wear out much sooner and require more maintenance than tunnels. Full life-cycle costs and benefits favor a tunnel over an elevated replacement. Tunnel costs must be fairly evaluated as the Committee deliberates in the coming months. We believe that the best way to reach a fair, defensible conclusion is to have the Committee convene an expert panel to review full life-cycle costs of both options (tunnel and elevated structure), current data on soil and other conditions, and deliver a cost range estimate for the SR 99 deep-bored inland bypass tunnel option, both for a six-lane and a four-lane configuration. We recommend that the Committee draw on international tunneling experts based in Puget Sound and elsewhere to convene this recommended panel assessment.

Furthermore, we would be remiss if we did not applaud your choice to analyze and consider the tunnel and Interstate 5 together. When you broadened the definition to include transportation effects from Elliott Bay to Interstate 5, we believe you made a good first choice. As articulated in the enclosed Puget Sound Business Journal op-ed, we believe that the combination of tolling, a deep-bore tunnel and I-5 express lanes would work together to fund transit, and cut congestion safely in an environmentally sound manner. Tolling will be a significant part of our region's transportation future, as evidenced by legislative actions in 2008 that show the issue is gaining traction. We look forward to more of the details of this comprehensive Urban Mobility analysis.

Finally, an inland deep-bored bypass tunnel on SR 99 could help limit vehicle miles traveled, drive transit improvements and help control greenhouse gas emissions. Additionally, electrostatic precipitators powered by clean electricity can be used to cleanse tunnel vehicle exhaust of particulate emissions, and technology is gradually being developed to neutralize the nitrogen dioxide emissions of vehicles in tunnels. Also worth noting is that modern ventilation methods and evacuation approaches are available that allow tunnel fires to be controlled.

Thank you again for your work on this important issue. We strongly encourage the option that is best for the region—the inland deep-bored bypass tunnel—be given fair and full analysis during your deliberations and in your report to the Governor, Mayor and King County Executive. Please do not hesitate to contact us if we may be of any assistance or answer any questions going forward.

Sincerely,

Bruce Agnew  
Policy Director  
Cascadia Center at Discovery Institute  
208 Columbia Street  
Seattle, WA 98104  
+1 (206) 292-0401 x113 direct  
+1 (206) 228-4011 mobile  
bagnew@discovery.org

Enclosures

RECOMMENDATIONS TO ALASKAN WAY VIADUCT STAKEHOLDERS ADVISORY COMMITTEE

CASCADIA CENTER  
DISCOVERY INSTITUTE

## **THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**

CASCADIA CENTER  
DISCOVERY INSTITUTE

ON DECEMBER 14, 2007, Cascadia Center hosted a three hour seminar in Seattle on the subject of deep-bore tunneling. The seminar, which included a discussion of local history and global examples, brought together experts in the field and from around the world. Ultimately, the question at hand was: Is a deep-bore bypass tunnel in the future for Alaskan Way Viaduct? Richard Prust, of Arup's Seattle office, was the lead event planner for identifying key topics and securing presenters.

Cascadia Center has long believed that a deep-bore bypass tunnel for the congested Highway 99 corridor could allow Seattle to fix the problem of the aging Alaskan Way Viaduct with minimal impacts on downtown during construction. December's session brought the tunnel issue again to the forefront of discussion. A capacity crowd joined our distinguished panel of deep-bore tunneling experts.

The following several pages offer a recap of the event. More importantly, in combination with the presentations from the panel on our Web site ([www.cascadiaproject.org](http://www.cascadiaproject.org)) this seminar report provides a reference for policy makers and others to quickly digest what some of the world's top tunneling experts have to say about a deep-bore bypass tunnel for the Alaskan Way Viaduct.

### **Seminar Summary\***

\*As reported in the *Puget Sound Business Journal*, December 28, 2007

### **IS DEEP-BORE TUNNEL BEST HOPE TO REPLACE VIADUCT?**

BY Glenn Pascall

The search for a practical successor to the Alaska Way Viaduct has taken our region on a roller-coaster ride. Two high-profile alternatives -- a new aerial structure and a cut-and-cover tunnel -- crashed when their cost in disruption plus construction proved prohibitive.

The issue became so hot that the architects of Proposition 1 didn't even put a viaduct solution in their complex and costly package, which nonetheless suffered defeat at the polls in November.

Amidst political turmoil, two alternatives have moved steadily along -- the

surface street option and a deep-bore bypass tunnel. Each has been nurtured by proponents more interested in making the case for their approach than in attacking others.

Moreover, the two approaches appear compatible since they would minimize disruption to the waterfront and downtown while connecting these two iconic parts of Seattle.

The bypass tunnel assists the surface street option by providing a capacity solution for the 60,000 vehicles that use the Viaduct each day as a through route, taking this load off the design of a surface street plan. Some strategists are already talking about a tunnel finance plan that includes funds which could be applied to surface street and transit amenities.

**THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**

CASCADIA CENTER  
DISCOVERY INSTITUTE

On Dec. 14, the Cascadia Center for Regional Development convened a seminar featuring global and regional experts on deep-bore tunneling. Several key topics were discussed before an audience of over 100 attendees.

The seminar moderator was Gary Lawrence, Urban Strategies Leader for Arup Consultants. He began by asking if there is a "solution set that more than adequately addresses" a range of issues that brought previous approaches to grief.

A roster of experts responded. John Reilly, a leader in the International Tunneling Association, asked, "Why elevated? Why surface? Why underground? Open this question up to the possibilities and then narrow the options to what is achievable, affordable and acceptable."

Alan Dyke, managing director for the high-speed rail route between London and the English Channel, said a tunnel under London was chosen because disruption and environmental mitigation requirements of a surface route through the city would be excessive. He added, "We picked a route that actually promoted redevelopment of derelict sites in the city."

The Paris A86 beltway automobile tunnel holds a similar lesson. Jeff Hall is vice president of Cofiroute, a subsidiary of Vinci, one of the largest construction firms in the world and builder of A86. Hall said Paris went through alternatives -- surface roads, a cut-and-cover tunnel -- and rejected them due to a quality of life issue: Protection of the Parisian greenbelt. "A deep-bore tunnel was the only way to do this while adding capacity."

Bob Park is president of Acciona Canada, whose parent firm was lead contractor on the Madrid M30 project, another beltway auto-tunnel. He reported, "Madrid chose a tunnel as the best way to reconnect neighborhoods, reduce emissions, regenerate its riverbank and develop new leisure areas."

Seattle's tunneling history is more extensive than many residents realize.

Red Robinson, lead geo-technician for locally-based engineers Shannon &

Wilson, described several of the more than 100 tunnels in Seattle that total over 65 miles in length. The 64-foot wide Mount Baker Tunnel on I-90 is the world's largest soil ridge tunnel.

Seattle City Council transportation committee chair Jan Drago added that in recent years, "We've been building deep bore tunnels in Seattle -- Third Avenue, Beacon Hill, Brightwater."

In opening remarks, Drago noted that "tunnel technology has changed significantly if not dramatically since we started searching for solutions to the viaduct."

Dick Robbins heads The Robbins company, a Seattle-based designer, maker and operator of tunnel-boring machines (TBMs). He said "big advances in tunnel technology are the result of steady progress that makes tunneling cheaper, faster and safer." In Red Robinson's words, "New technology makes the impossible possible."

One key element, Lawrence said, is that "the scale is increasing, to solve problems that smaller-bore tunnels couldn't solve." Reilly confirmed this. "Only now are we getting to TBM diameters that can handle traffic and emergency lane needs."

Jack Brockway is senior vice president for the USA division of Herrenknecht, a German firm that is the recognized world leader in TBMs. He reported that "each machine is designed for the kind of ground it is going through, with a unique mix of cutter heads for the geology. It is custom-built and assembled in the shop or at the job site. Big TBM's are refurbished, modified and re-used."

Reilly noted that "Politics is often focused on initial capital cost, but we must look to total life-cycle cost. Tunnels cost more to build but less to maintain. They last a lot longer than elevated structures or surface streets."

For this reason, Reilly believes tunnel construction should be funded through mechanisms that recognize long-term benefits as well as higher initial cost.

Drago commented that the Seattle City Council "does this with utility

#### **THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**

investments but not transportation. Life-cycle cost analysis should be part of this decision."

The seminar steered clear of debates over precise cost estimates for a Seattle tunnel but offered illuminating examples. Dyke noted that the 23-mile long London rail tunnel was built in 19 months and cost \$75 million per mile -- about half what historical experience would suggest. "One reason was early involvement of contractors through price competition and performance incentives."

But Dyke added that "a holistic assessment of costs, risks and opportunities is essential. London's bored tunnel project would not fly on transport benefits alone. Property gains and environmental improvements create value that should help contribute to project costs."

Lawrence agreed that real estate improvements can help pay for the project. "In Asia, some rail projects are paid for entirely by the sale of air rights," he noted. The analogy for Seattle would be the development gains that would come from removing the viaduct.

Another source of financing is to partner with pension funds held by unions, or even public employee funds such as California's CALPERS. "Transportation projects and tunnels around the U.S. have union pension funds in their financing package -- and we get the construction work," said John Littel of the Northwest Regional Council of Carpenters.

Littel described how the building trades unions combine pension funds with equity investment in the Northwest and elsewhere, working with investment firms to identify infrastructure projects.

Drago concluded the session by observing, "A tunnel is part of a larger system, not an isolated project. How does a solution for Highway 99 fit into our transportation and transit system?" The Cascadia Center's seminar helped move the deep-bore bypass tunnel along as a viable option that could combine with a surface street strategy to put Seattle in the "post-viaduct" era.

## Seminar Presentation Recaps

The seminar featured seven presentations. Highlights, including select graphics, of each appear below. The program opened with an introduction from Arup consultants.

### Setting the Context

**Gary Lawrence**, *Urban Strategies Leader, Arup consultants*

Is there a solution set for Viaduct replacement that more than adequately:

- Provides capacity, without shifts to I-5, for passenger and freight traffic that currently uses the Viaduct as a through route
- Serves longer-term demand management and mode shift goals
- Keeps the Viaduct open and operating until alternative capacity is in place
- Eliminates the risk of cut-and-cover tunneling through the muck along the waterfront
- Provides for surface transportation to address local capacity needs, public amenities and improved real estate values along the most important real estate corridor in the Pacific Northwest
- Maintains the viability of local freight movement from southern to northern industrial areas
- Provides for better near and long-term cost containment and risk management as compared to other construction and operational alternatives

## THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA

## Seattle's Tunneling History

**Red Robinson**, *Director of Underground Services, Shannon and Wilson*

Seattle has a remarkably extensive tunneling history. The first tunnels were for sewers. Subsequent tunnels were for railroads, utilities, highways, transit and pedestrians. Seattle has more than 100 tunnels, totaling over 65 miles in length

The first tunnel-boring machine (TBM) in Seattle dug the Ravenna sewer tunnel in 1910. The Great Northern Railway tunnel built in 1903-05 is still in use. Advanced technology such as a traveling steel arch concrete form was used for the Hanford Street tunnel in 1929. And the Mt. Baker tunnel, built in 1983-85, remains the world's largest soil ridge tunnel.

Seattle was the site for first uses in the Northwest of a host of tunneling technology, including electric locomotives, gasketed segmental liners, earth pressure balance TBM's, polymer additives, waterproof membranes, compressed air support, traveling steel forms, digger shields, and shotcrete support. Seattle was also first in the region to build a dual-use transit tunnel and use



**SEATTLE'S FIRST TBM, RAVENNA 1910**

risk-sharing contracts and finite element analysis.

Tunnel boring from 1960 to the present in Seattle and worldwide has introduced an array of new tools and techniques that have "made the impossible possible." These technologies include: mechanized shields and tunnel boring machines; electric and diesel powered muck trains; muck removal with conveyors and slurry lines;

support with steel ribs, shotcrete, and concrete; dewatering with deep wells, ejectors and vacuum; soil stabilization with cement and chemical grout; laser guidance and computerized monitoring instrumentation to monitor soil movement, tunnel deformation, water-levels and structure loads.

## Making the Decision: Above-ground or Underground?

**John Reilly**, *John Reilly Associates; Board Member, International Tunneling Association*

In many parts of the world it is very difficult to obtain funding and approval for underground projects even if the long-term benefits are positive because the higher initial capital cost of underground projects means that a cheaper elevated or above-ground project is frequently chosen.

Selection of an alternative only on the basis of initial capital cost is misleading and in many cases precludes the realization of very substantial long-term benefits. Long-term/life cycle value (benefits + costs) needs to be considered. We define life-cycle as the present value of all benefits plus capital and operating costs of the facility.

One cost comparison, published in the journal "T&T North America" for December 2005, estimated cost differentials as typical for transportation infrastructure projects. Using at-grade surface structures as the base line, it found the following:

## THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA

	AT-GRADE	ELEVATED	CUT-AND-COVER	BORED
Construction Cost	1.0	2.8	3.7	3.2
Annual Cost	1.0	1.4	0.5	0.4

A good model for evaluating comparisons such as these is the cost estimation validation process used by the Washington State Department of Transportation. This method assigns degrees of probability to various levels of cost within a range.

Tunnels and underground structures last a significantly longer time than above-ground structures—about 50 years for above-ground and over 100 years for tunnels. Many historic tunnels are still in useful service today (e.g. the 104-year old railroad tunnel under Seattle).

Longer service life means that the present value of a tunnel, including or excluding other benefits, is probably more than an elevated structure, even though the initial capital cost of the elevated is less than the tunnel.



ALTERNATE ROUTES FOR SR 99 THROUGH DOWNTOWN SEATTLE

Benefit-cost analysis should include capital, operating and maintenance costs plus direct and indirect benefits such as:

- Road user time savings, public transport user time savings, travel time variability, pedestrian time savings, vehicle operating cost savings, accident reduction, and longer facility life.
- Less tangible environmental and sustainability benefits related to increased land value, increased amenities (parks etc.), less noise & pollution, energy savings and reductions in greenhouse gas emissions. An equivalent value should be credited for these factors.

In summary, to assure a more equitable analysis in selection of underground alternatives, the case needs to be made to the public, government agencies and political decision-makers that:

- Planning and public policy should consider long-term life-cycle costs and benefits.
- Long-term life-cycle costs and benefits need to be quantified through an accepted methodology.
- Benefits need to be communicated to the public and political decision-makers.
- The political process should recognize that this is an appropriate planning and selection process.
- A funding mechanism must be identified that will support a higher initial capital cost in exchange for greater community benefits and lower M&O costs.

#### THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA



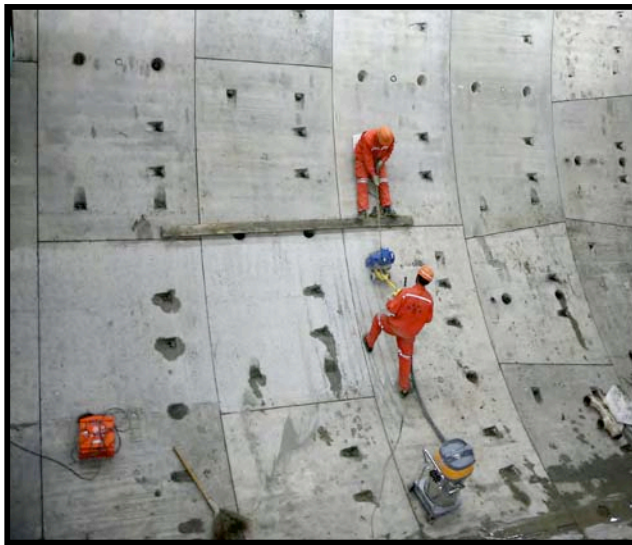
## **Tunnel Boring Machines: The State of the Art**

**Jack Brockway**, *Senior Vice President, Herrenknecht Tunnelling Systems USA*

Herrenknecht is recognized as the premier manufacturer of tunnel boring machines (TBM's) in the world. Every machine is custom designed for the kind of ground it is going through, with a unique mix of cutter heads for the geology. These mixshield machines are assembled in the shop or at the job site and after the project is complete, big TBM's are refurbished, modified and re-used.

The range of major projects around the world using Herrenknecht large-diameter machines is remarkable. Examples include the 4th Elbe Crossing in Germany, the Westerschelde tunnel in the Netherlands, and the S-246 Hallandsås tunnel in Sweden.

Sizes are steadily increasing. The Barcelona Metro Line 9 tunnel in Spain has a diameter of more than 12 meters, The Levortovo tunnel in Moscow is the world's largest tunnel so far bored by a mixshield machine, to a 14.2 meter diameter. The upcoming Shanghai tunnel will be even larger at 15 meters.



**WORKERS CLEANING SHANGHAI TUNNEL**

Other notable projects include the Malaysia SMART (stormwater management and auto route tunnel) and the Gotthard tunnel that will save one hour driving time between Milan, Italy and Basel, Switzerland.

Tunneling involves dealing with pressures from all directions that are normally 6.5 times atmospheric pressure. In extreme cases, pressures may be double this level. The pressure on tunneling machines can be greatly reduced by systems based on slurry, air, or earth. It is this technology that has enabled tunnel diameters to be much larger.

## **The Paris A86 Ring Road Automobile Tunnel**

**Jeff Hall**, *Vice President - Business Development, Cofiroute*

A tunnel was chosen for completion of the missing segment in a second ring road around Paris.

The underground solution allows:

- Reduction of harmful effects during construction (Disruption)
- Preservation of the forested land of the Parisian greenbelt (Landscape)
- Avoidance of harmful effects in residential areas (Noise)
- Limitation of harmful effects on historic monuments (Patrimony)
- Mitigation of surface congestion (Traffic)
- Reduction of greenhouse gas emissions (Air Quality)

A Value Pricing Policy was chosen as the means of keeping the tunnels congestion-free while providing for the financing of construction and operations.

The toll varies from 5 € during peak hours to 3.5 € during normal hours to 2€ during the night. Subscriptions can be purchased that whose cost varies according to the number of trips per month. The tunnel will carry 70,000 vehicles per day and a 15 percent reduction in surface traffic expected.

## **THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**



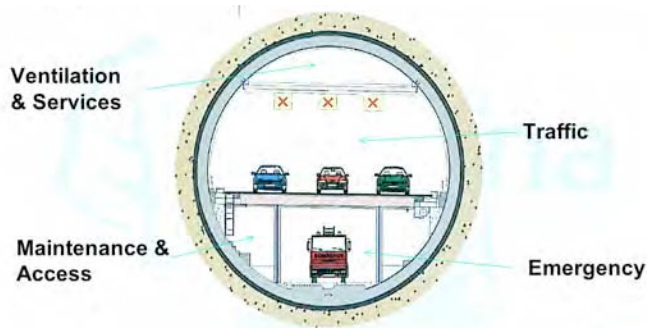
## The Madrid M30 Automobile Tunnel Project

**Bob Park**, *President, Acciona Infrastructures Canada Ltd.*

The M-30 was originally built in the 1960s using technology of the period. That distributed traffic radially. The M-40 was built in the 1990s as an external perimeter to M-30. Traffic has outgrown the system and an upgraded M-30 was required.

Project deliverables were multiple and complex: To improve traffic flow, upgrade access and egress, provide a new East-West axis and a new South bypass, offer connections to the A-4 and M-40 routes and the South bus terminal, and regenerate the Manzanares River bank.

The financing structure was based on a local-government owned company that was separate from municipal budgets and Private Partner Participation of almost 50 percent, responsible for O&M management during the next 35 years.



Social and Economic Benefits were the decisive factor in selecting a tunnel to provide the capacity and route. Social benefits include re-connecting neighborhoods, improving accessibility, reducing accidents, decreasing contamination, regenerating the riverbank, and providing new recreational facilities.

Environmental effects include: reduced fuel consumption, decreased gas emissions, lower noise levels, creation of new green space, and protection of the Puente De Toledo.

## The Metro London - Channel Tunnel Rail Line (CTRL)

**Alan Dyke**, *Arup, former Managing Director, London-to-Channel high-speed rail project*

Some 110 km (70 miles) of new high-speed railway between central London and the Channel Tunnel to Continental Europe was successfully completed on time and on budget.

This was not just a new railway but the catalyst for huge regeneration of derelict industrial waste lands, environmental improvements and the refurbishment of London's historic St Pancras Station.

London's route choices were difficult because the route would have to cross 20km (12 miles) of heavily built-up residential and industrial development. A new surface alignment was found to be too expensive and virtually impossible to obtain consensus on any specific route.

The reuse of existing railway corridors appeared to be an obvious choice, as routes exist, but the combination of cost, disruption and risks made this option unattractive. The drawbacks included:

- Displacement of existing traffic, Consequences were difficult to predict and cost impact uncertain.
- Risk arising from the condition of the existing assets. The 150-year-old infrastructure was not fit for a new purpose.
- Safety risk alongside live railways and roads was likely to cause additional accidents.
- Track alignment constraints would impact performance.
- Environmental mitigation expenses would be extensive and indeterminate.

A tunnel route was considered in the traditional view to be high risk and expensive. There was concern about surface settlements or even collapse, programme delays and cost increases.

These concerns were based on experience with the crude technology of the past. The CTRL  
**THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**

experience is that tunnels can now be delivered safely at a predictable cost and program outcome by using professional management and sophisticated but proven technology.

The Solution was to provide access into central London via 36 km (23 miles) of 7.15m (23ft 6in) internal diameter tunnel. The route links derelict sites across east London and at the terminus, providing ideal construction sites and future development opportunities.

A larger vision was required. The CTRL project would not fly on transport benefits alone. By focusing on wider benefits in property gains and environmental improvements, the politicians and general public were won over. Capturing the property benefits to contribute to the project costs requires a long-term planning framework. Key elements for success included an informed client with an investment in planning and design; an experienced and professional project management team; careful selection of alignment and construction sites; a holistic assessment of cost, risk and opportunities; early contractor involvement combined with price; a Contract that contains incentives for all parties; and a performance-based specification.

CTRL delivered. There was no settlement damage to surface properties. The tunnel is 25 metres in average depth, with a face loss less than 0.5 percent. No trucks were on the roads during construction, and rail and onsite disposal were utilized. There was no disruption to the every day life of London and no serious accidents. Forty-five hectares of low-lying land was reclaimed at what is now the site of London's 2012 Olympic Park. Bottom line: £12 billion in regeneration investment for an outlay of £6 billion for the new railway.

ARUP

WITH THANKS TO ARUP FOR THEIR  
SUPPORT AND INVOLVEMENT WITH THE  
DEC. 14, 2007 SEMINAR,  
"THE DEEP BORE TUNNEL:  
A PRACTICAL SOLUTION FOR THE POST-  
VIADUCT ERA."

THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA

*Author*

Glenn Pascall  
Regional Economist & Author

*Contributing Editor*

Mike Wussow  
Director of Public Affairs, Cascadia Center at Discovery Institute

Copies available at [www.cascadiaproject.org](http://www.cascadiaproject.org)

Or by writing to:

Cascadia Center at Discovery Institute  
Attn: Mike Wussow, Managing Editor  
208 Columbia Street  
Seattle, Washington 98104

**THE DEEP BORE TUNNEL: A PRACTICAL SOLUTION FOR THE POST-VIADUCT ERA**

CASCADIA CENTER  
DISCOVERY INSTITUTE



## Supplemental Tunnel Project Data Examples

The information below, a supplement to the content in the report from our December seminar, provides a snapshot view of several deep-bored vehicle tunnel projects around the globe. The chart below shows raw costs and numbers. Construction times for the samples below range from four to eight years. Tunnel boring technology is increasingly sophisticated, enabling safe and secure deep bored tunnels even in softer soils (*see* Nanjing, below).

At a future date, Cascadia Center will consider options for more thoroughly examining deep-bored projects and would, at the conclusion of such an examination, share a sophisticated analysis with the Stakeholders Advisory Committee and others.

	PARIS A86 Hwy	ZURICH Uetliberg	DUBLIN <sup>2</sup> Sea Port	MADRID M30 South Bypass	HAMBURG Elbe River	WUHAN Yangtze River	NANJING <sup>2</sup> Chang-jiang	SHANGHAI <sup>2</sup> Yangtze
Length (miles)	5.25	2.73	3.5	2.2	1.9	2.24	3.7	15.8
Total Cost <sup>1</sup>	3,050	1,080	1,150	570	768	239	422	1,600
<b>Cost / Mile<sup>1</sup></b>	<b>580</b>	<b>396</b>	<b>328</b>	<b>259</b>	<b>404</b>	<b>106</b>	<b>114</b>	<b>290</b>
Total Lanes	6	4	4	6	3	4	6	6
TBM Type	All Terrain	Boring Extender	Hard-rock	EPB Shield	Mixshield	Slurry	Slurry	Slurry

<sup>1</sup>All costs in millions of USD, using current costs.

<sup>2</sup>Dublin, Nanjing, and Shanghai each included cut & cover tunnel sections which could not be analyzed separately.

### Additional Notes & Explanations of Data Examples

- **Nanjing Changjiang Tunnel Project:** Soft river deposits of clay, silt and sand were processed with a “slurry” type TBM, designed to drill in soft materials.
- **Paris A86 Tunnel:** To open 08-09; will complete second, outer ring road around Paris, the A86; completely financed by private concessionaire, Cofiroute, using bonds, and time-variable tolls.
- **Uetliberg Tunnel, Zurich:** Tunnel fills gap in national road network and provides quick, environmentally friendly traffic diversion away from Zurich.
- **Shanghai Yangtze River Tunnel and Bridge:** 15.8 mile expressway, including 5.5-mile deep-bored twin tunnels, plus viaduct and bridge.

**SUPPLEMENTAL TUNNEL PROJECT DATA EXAMPLES**  
**RECOMMENDATIONS TO ALASKAN WAY VIADUCT STAKEHOLDERS ADVISORY COMMITTEE**

Friday, August 10, 2007

## Viaduct bypass, I-5 expansion should be linked

by Bruce Agnew

**T**he shocking collapse of the Minneapolis Interstate 35W bridge will no doubt aid the campaign for the multibillion-dollar roads-and-transit package facing central Puget Sound voters in November. Yet two crucial transportation projects relevant to the Minnesota tragedy are partially on hold -- replacement of the central waterfront section of Alaska Way Viaduct on State Route 99, and full funding for reconstruction of the 40-year-old stretch of Interstate 5 from Northgate to Tukwila.

Earlier this year, Seattle voters rejected two ideas for replacement of the viaduct -- a larger aerial structure and a cut-and-cover four-lane waterfront tunnel. State transportation leaders have approved nearly \$1 billion in improvements to the north and south ends of the viaduct to fix about 55 percent of the seismically vulnerable structure. Yet only the so-called "surface transit" option for the central waterfront is under continuing study by the city of Seattle and the state.

At Discovery Institute's Cascadia Center, we support tearing down the aerial viaduct and have endorsed several aspects of the surface transit option, including bus rapid transit, a circular streetcar network emanating from the waterfront, and return of the "Mosquito Fleet" to expand water taxi and passenger-only ferry options.

However, any notion that the viaduct's 110,000 daily vehicle trips can be replaced by a series of transit enhancements fails to comprehend the complexity of moving freight in a constricted north-south corridor. Simply put, I-5 can't take any more traffic and freight can't take a bus.

Solutions so far have been piecemeal and money is scarce. The Washington state Legislature allotted \$21 million in its construction budget to begin repaving sections of I-5 between Federal Way and Northgate, initially around Spokane Street. Repaving I-5 is an important first step, but alone will not eliminate bottlenecks and poorly designed ramps, for which much of the funding has been pushed to 2017 and beyond.

We can't look to the federal government for help. The Highway Trust Fund will have a \$4 billion deficit in 2009, and Congress has shown no willingness to raise the 18.3-cent per gallon federal gas tax. I-5 in central Seattle carries 260,000 vehicles a day, rivaling sections in Los Angeles. The absence of the I-5 rebuild/reconstruction on the regional transportation ballot is a head-scratcher at best. Indeed, I-5 was completed around 1967 -- roughly the same time as I-35W in Minnesota.

So we propose a bold -- some would say radical -- rethink. Our plan would consider both I-5 reconstruction and added capacity and replacement of the central section of the Alaskan Way Viaduct, within the context of regionwide tolling and partnerships for private capital.

A deep-bored tunnel through downtown to replace the viaduct, beginning at Sodo and splitting to either State Route 99 east of the Seattle Center or continuing to the Mercer/I-5 ramp, would segregate local traffic from through traffic, and would avoid the construction disruptions on the central waterfront that threaten businesses.

Obayashi Corp. is building a deep twin-bore tunnel in Seattle right now for Sound Transit's light rail line. The 21-foot-wide twin tunnels are about a mile long and cost about \$300 million total. As a replacement for the viaduct, twin bores would need to be 35-40 feet wide to accommodate three lanes of traffic in each direction, including trucks. Recently in the Swiss Alps, a 21-mile deep bore tunnel was completed at a cost of \$3.2 billion -- evidence of major advances in bored tunneling since the state rejected it as an option in 2001.

In addition to accelerating the reconstruction of I-5, our plan would redesign the reversible express lanes from Northgate to downtown. We would eliminate the notorious backup caused when the lanes "switch" from north to south by designing an additional "contra flow lane" in the opposite direction.

This would allow the express lanes to operate 24 hours a day in each direction and provide an additional through lane in the difficult downtown area, which currently has only two through lanes. Overpasses and ramps would have to be modified or removed, but a bottleneck of gigantic proportions would be eliminated, and it could be done on the existing footprint. For this premium service, a variable toll would be charged for the express lanes only; drivers could still access the regular lanes free. We'd dedicate a portion of the toll to expand bus rapid transit options as a supplement to current transit investments on I-5 and Highway 99.

How do we pay for such a feat of engineering without added taxpayer exposure? Answer: In addition to tolls, union and public employee pension funds could be invested in these projects and would pay back a return over many years.

Earlier this year, Cascadia and the Gallatin Group hosted former U.S. House of Representatives Majority Leader Dick Gephardt, now with Goldman Sachs, who said the \$7 billion building trades' pension funds were "patient funds looking for infrastructure investments in America and the Northwest." In fact, union pension funds were used in Seattle recently to construct the Pacific Place garage. Calpers, the major California pension fund, is also considering joint investments with public agencies in infrastructure.

Gov. Chris Gregoire and the Legislature should consider modifying state law to allow this partnership with union pension funds. And if the November ballot measure fails, the State Route 520 bridge should be added to the I-5/Highway 99 pilot project.

Our failure to think big in the past is one reason we're in today's transportation mess. Let's start now to change that.

*Bruce Agnew is director of Discovery Institute's Cascadia Center For Regional Development.*

Copyright © 2007 Puget Sound Business Journal

Friday, December 28, 2007

## Is deep-bore tunnel best hope to replace viaduct?

by Glenn R. Pascall

**T**he search for a practical successor to the Alaska Way Viaduct has taken our region on a roller-coaster ride. Two high-profile alternatives -- a new aerial structure and a cut-and-cover tunnel -- crashed when their cost in disruption plus construction proved prohibitive.

The issue became so hot that the architects of Proposition 1 didn't even put a viaduct solution in their complex and costly package, which nonetheless suffered defeat at the polls in November.

Amidst political turmoil, two alternatives have moved steadily along -- the surface street option and a deep-bore bypass tunnel. Each has been nurtured by proponents more interested in making the case for their approach than in attacking others.

Moreover, the two approaches appear compatible since they would minimize disruption to the waterfront and downtown while connecting these two iconic parts of Seattle.

The bypass tunnel assists the surface street option by providing a capacity solution for the 60,000 vehicles that use the Viaduct each day as a through route, taking this load off the design of a surface street plan. Some strategists are already talking about a tunnel finance plan that includes funds which could

be applied to surface street and transit amenities.

On Dec. 14, the Cascadia Center for Regional Development convened a seminar featuring global and regional experts on deep-bore tunneling. Several key topics were discussed before an audience of over 100 attendees.

The seminar moderator was Gary Lawrence, Urban Strategies Leader for Arup Consultants. He began by asking if there is a "solution set that more than adequately addresses" a range of issues that brought previous approaches to grief.

A roster of experts responded. John Reilly, a leader in the International Tunneling Association, asked, "Why elevated? Why surface? Why underground? Open this question up to the possibilities and then narrow the options to what is achievable, affordable and acceptable."

Alan Dyke, managing director for the high-speed rail route between London and the English Channel, said a tunnel under London was chosen because disruption and environmental mitigation requirements of a surface route through the city would be excessive. He added, "We picked a route that actually promoted redevelopment of derelict sites in the city."

The Paris A86 beltway automobile tunnel holds a similar lesson. Jeff Hall is vice president of Cofiroute, a subsidiary of Vinci, one of the largest construction firms in the world and builder of A86. Hall said Paris went through alternatives -- surface roads, a cut-and-cover tunnel -- and rejected them due to a quality of life issue: Protection of the Parisian greenbelt. "A deep-bore tunnel was the only way to do this while adding capacity."

Bob Park is president of Acciona Canada, whose parent firm was lead contractor on the Madrid M30 project, another beltway auto-tunnel. He reported, "Madrid chose a tunnel as the best way to reconnect neighborhoods, reduce emissions, regenerate its riverbank and develop new leisure areas."

Seattle's tunneling history is more extensive than many residents realize.

Red Robinson, lead geo-technician for locally-based engineers Shannon & Wilson, described several of the more than 100 tunnels in Seattle that total over 65 miles in length. The 64-foot wide Mount Baker Tunnel on I-90 is the world's largest soil ridge tunnel.

Seattle City Council transportation committee chair Jan Drago added that in recent years, "We've been building deep bore tunnels in Seattle -- Third Avenue, Beacon Hill, Brightwater."

In opening remarks, Drago noted that "tunnel technology has changed significantly if not dramatically since we started searching for solutions to the viaduct."

Dick Robbins heads The Robbins company, a Seattle-based designer, maker and operator of tunnel-boring machines (TBMs). He said

"big advances in tunnel technology are the result of steady progress that makes tunneling cheaper, faster and safer." In Red Robinson's words, "New technology makes the impossible possible."

One key element, Lawrence said, is that "the scale is increasing, to solve problems that smaller-bore tunnels couldn't solve." Reilly confirmed this. "Only now are we getting to TBM diameters that can handle traffic and emergency lane needs."

Jack Brockway is senior vice president for the USA division of Herrenknecht, a German firm that is the recognized world leader in TBMs. He reported that "each machine is designed for the kind of ground it is going through, with a unique mix of cutter heads for the geology. It is custom-built and assembled in the shop or at the job site. Big TBM's are refurbished, modified and re-used."

Reilly noted that "Politics is often focused on initial capital cost, but we must look to total life-cycle cost. Tunnels cost more to build but less to maintain. They last a lot longer than elevated structures or surface streets."

For this reason, Reilly believes tunnel construction should be funded through mechanisms that recognize long-term benefits as well as higher initial cost.

Drago commented that the Seattle City Council "does this with utility investments but not transportation. Life-cycle cost analysis should be part of this decision."

The seminar steered clear of debates over precise cost estimates for a Seattle tunnel but offered illuminating examples. Dyke noted that the 23-mile long London rail tunnel was built in 19 months and cost \$75



million per mile -- about half what historical experience would suggest. "One reason was early involvement of contractors through price competition and performance incentives."

But Dyke added that "a holistic assessment of costs, risks and opportunities is essential. London's bored tunnel project would not fly on transport benefits alone. Property gains and environmental improvements create value that should help contribute to project costs."

Lawrence agreed that real estate improvements can help pay for the project. "In Asia, some rail projects are paid for entirely by the sale of air rights," he noted. The analogy for Seattle would be the development gains that would come from removing the viaduct.

Another source of financing is to partner with pension funds held by unions, or even public employee funds such as California's CALPERS. "Transportation projects and tunnels around the U.S. have union pension funds in their financing package -- and we get the construction work," said John Littel of the Northwest Regional Council of Carpenters.

Littel described how the building trades unions combine pension funds with equity investment in the Northwest and elsewhere, working with investment firms to identify infrastructure projects.

Drago concluded the session by observing, "A tunnel is part of a larger system, not an isolated project. How does a solution for Highway 99 fit into our transportation and transit system?" The Cascadia Center's seminar helped move the deep-bore bypass tunnel along as a viable option that could combine with a surface street strategy to put Seattle in the "post-viaduct" era.

*Glenn Pascall's column appears regularly in the Puget Sound Business Journal. Pascall is an economist who has taught and done research for the Evans School of Public Affairs at the University of Washington. He has directed economic impact studies for the aerospace and wood-product industries, among others, and developed strategies for state economic vitality and affordable housing.*

Copyright © 2007 Puget Sound Business Journal

Friday, March 30, 2007

## ‘Other’ tunnel option must withstand scrutiny

by Glenn R. Pascall

**T**wo weeks ago in this space, I set forth the case for a bored tunnel to replace the Alaskan Way Viaduct. Like proponents of other alternatives, I laid out a series of arguments. Yet, we are at the point in a long and hard process where what to do is equaled in importance by how we seek to reach broad agreement.

Every participant in the discussion is now called upon to discipline advocacy with analytical rigor, accompanied by a spirit of openness toward the concerns and priorities of others. A precondition is to separate the discussion of viable alternatives from the bruising politics of the issue. Gov. Chris Gregoire and Seattle Mayor Greg Nickels got off to an excellent start in this direction after the "no-no" advisory vote outcome on March 13.

With the mayor's assent, the governor put forth a sensible strategy that calls for moving immediately to shore up the safety of the existing structure, while making progress on construction that will be relevant regardless of the final design decision.

The two leaders also agreed on a political timeout. One reason no one has prevailed so far is that no compelling solution has emerged. But reaching agreement will require inclusive outreach as well as a persuasive proposal. Even the most attractive alternative will lack broad-based

appeal unless it takes into account a wide range of legitimate concerns.

Mutual respect is the starting point. One group of combatants in the recent gladiatorial games has shown an admirable ability to stay on point without trashing others. "Surface option" advocates led by Cary Moon have stressed positive possibilities, and their option was the "default winner" on March 13. But there's one crucial challenge they may have "solved" too easily.

Unlike the Embarcadero Freeway, whose removal liberated the urban ambiance of a part of San Francisco, the viaduct is a vital through-route and a key link within the larger metro region. An estimated two-thirds of trips on the elevated roadway enable travelers to connect two points that are relatively distant from downtown.

Removing this capacity would require an unprecedented degree of shift to bus-and-bicycle transport to avoid paralyzing gridlock on Interstate 5. Even in Seattle, the assumption of such a behavioral response is heroic. Thus it is a shaky basis for a policy decision that will significantly shape our regional reality for the coming half-century or longer.

Yet, there may be a basis for compromise. A bored tunnel would be simpler to design and easier to build if it were a through-route with

no downtown ramps. And those who commute to and from downtown by bus, auto or bicycle could travel on surface streets but wouldn't have to compete for space each day with 70,000 vehicles using the bored tunnel as a bypass.

A related dimension is freight mobility, which scores high as a factor in urban economic vitality. Avoidance of construction disruption at the waterfront would contribute hugely on this front. And any well-designed solution to regional circulation will have spillover benefits for truck traffic related to the city and port. Beyond this, focused thinking about how goods movement interacts with a bypass could generate synergy between the viaduct solution and freight mobility.

A core issue is safety, which ranks as the state's top priority. In this writer's view, the governor's evident anxiety about the viaduct has not been driven by politics. Its true source is Gregoire's abiding concern regarding the depth of legal, financial and moral liability if the viaduct were to suffer catastrophic failure and lives were lost before a repair and replacement plan was approved.

Despite visceral fears, a tunnel is perhaps the safest location in an earthquake. Tunnels move with the ground motion set up by an earthquake, which permits them to stay intact and to operate without interruption. This was proved dramatically in the 1989 Loma Prieta earthquake in the San Francisco Bay Area. Many aerial freeway structures collapsed, while the BART rail tunnels operated without interruption.

The seawall would not form part of bored tunnel construction. This has two major advantages. First, since the seawall does not have to be coordinated with the roadway, neither would be compromised by the requirements of design integration. Second, the seawall can be repaired or rebuilt on an

as-needed basis and as waterfront development takes place, rather than being affected by the construction schedule for viaduct replacement. In this way, both disruption and costs can be localized and managed.

The overall cost picture is complex, no matter what we do. For example, there's the "deconstruction cost" of dismantling the viaduct and redeveloping the site. To what degree can this cost be offset by "value capture" from new projects on or near what was the route of the viaduct?

Can a deep-bore tunnel design be developed that is free from fatal flaws? The answer requires rigorous analysis. Even if it survives the tests of feasibility, this approach must integrate priorities and concerns that range from freight mobility to urban ambiance.

A treasured book in my library is architect and civic activist Victor Steinbrueck's "Seattle Cityscape," published in 1962. A case might be made that Steinbrueck envisioned Seattle as the city that Portland has actually become. But the sheer economic dynamism of Boeing, Microsoft and a bevy of other corporate heavyweights assured this would not be Seattle's destiny. Something larger and more driven, starker and yet perhaps more significant, was in the works.

Our challenge is to take a moment of inescapable change and make it serve that destiny.

*Glenn Pascall's column appears regularly in the Puget Sound Business Journal. Pascall is an economist who has taught and done research for the Evans School of Public Affairs at the University of Washington. He has directed economic impact studies for the aerospace and wood-product industries, among others, and developed strategies for state economic vitality and affordable housing.*

Copyright © 2007 Puget Sound Business Journal

Friday, March 16, 2007

## Bored By All Those Viaduct Choices? Think Again

by Glenn R. Pascall

**T**his week's voter rejection of both Alaskan Way Viaduct replacement options on the ballot in Seattle reflects the fact that each has serious drawbacks that prevent it from being the clear choice. The surface-street option, the default winner in the election, has its own challenge: gridlock or a massive shift in commuter behavior.

A viaduct rebuild sacrifices the rare opportunity to remove an urban eyesore and reconnect Seattle's downtown with the waterfront, while a cut-and-cover tunnel involves high costs and/or design compromises. Both options risk severe construction disruption. Moreover, the route is located in highly unstable ground conditions, with poorly placed fill and soft marine deposits.

The question is whether there is a way to liberate the part of the city that has been violated by the viaduct, while maintaining essential transport capacity, holding construction disruption to an absolute minimum, and financing the project's dollar cost in the very low billions.

There may be an answer: the Bored Tunnel Alternative. Truth in packaging: I've been working as an adviser to a group that has been examining alternatives over the past few months and has focused on this one as the most promising.

Members of the dialogue include Bruce Agnew, director of the Cascadia Center; John Wilson, a principal at the Gallatin Group; and Gary Lawrence, a principal at Arup consultants. As of this writing, they are poised to put forth the case for such an approach soon.

Bored tunnels have been built around the world for decades, but the technology of boring machines (called "moles") has advanced by leaps and bounds in recent years. This has enabled larger diameters (up to 51 feet), increased productivity and greater control of ground movements in a wide variety of conditions.

Recent bored roadway tunnels include the M30 tunnel in Madrid, the SMART tunnel in Malaysia, the 4th Elbe Crossing in Germany, and the A86 West Tunnel in Paris. This type of technology is being used in Seattle by Sound Transit on its Beacon Hill tunnel, and is proposed for the University Link Extension and for King County's Brightwater project.

Several years ago, state transportation engineers evaluated a 2.5-mile bored tunnel and ruled out this option because of high estimated costs. However, cost data for recent bored tunnel projects around the world indicate huge gains in economy of construction. Projected or actual costs of \$270 million or less per mile are a small fraction of the original Washington state Department of Transportation estimate, and far below costs for an elevated structure or a cut-and-cover tunnel.

A combination of factors makes bored tunnels in this country more expensive than elsewhere. Cost estimates for projects on Interstate 710 in California and at the Port of Miami run up to \$860 million per mile. However, these projects would accommodate port-related heavy truck

traffic that would not be allowed either on a new elevated structure or a tunnel here.

Even so, using this top end conservative baseline for Seattle translates into \$1.5 billion for a single-bore, 1.75-mile tunnel, or \$3 billion for a double bore that would carry six lanes. The compact length of the bored tunnel is due to more direct routing through downtown.

Another advantage: When the bore is deep enough that the surface area above the tunnel is not disturbed, construction disruption for a bored tunnel is minimal. This means no open excavations, no utilities diversions (other than those associated with demolishing the viaduct) and no trucks through downtown streets. The vast majority of the visible work would be focused at the portals.

Many possibilities exist for locating a single or twin bored tunnel configuration. All options have a common theme: They would be located in firm ground, away from the very poor fill material and soft marine clays along the waterfront. The alignment would likely run from near the stadiums to the south of downtown and follow downtown avenues before connecting to State Route 99 in the vicinity of Denny Way or Mercer Street.

The tunnels would run at least 40 feet below ground and would pass below the existing freight rail tunnel. They would also bypass the existing viaduct, which would be kept open during construction, thus avoiding the large economic costs of disruption related to proposed alternatives.

The completed portals would represent valuable pieces of real estate. The portal structure can be designed to carry high-rise building loads that would allow future development of the site, adding to residential property values near downtown and stimulating new development in the surrounding area.

The options that have been put forth suffer from shortcomings related to cost, capacity, and design impacts. If this were not the case, the protracted debate would have long since ended

and agreement reached on a preferred alternative. But the debate continues because all parties find themselves defending deeply flawed approaches.

The bored tunnel alternative is a proven technology that could break the deadlock among advocates. It combines capacity with minimal disruption, at an affordable price, and offers the bonus of reconnecting the waterfront and downtown.

*Glenn Pascall's column appears regularly in the Puget Sound Business Journal. Pascall is an economist who has taught and done research for the Evans School of Public Affairs at the University of Washington. He has directed economic impact studies for the aerospace and wood-product industries, among others, and developed strategies for state economic vitality and affordable housing.*

Copyright © 2007 Puget Sound Business Journal